A REVIEW OF RESEARCH RELATED TO DEVELOPMENT OF GRAZING SYSTEMS ON NATIVE RANGES OF THE WESTERN UNITED STATES[1]

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Abstract

Research studies on grazing systems on native range in the 17 contiguous Western States are reviewed. Yearlong-continuous grazing was superior to seasonal grazing on the California annual rangelands. There was only limited success with any grazing scheme other than continuous on rangelands grazed only for a part of the year (seasonal ranges). The deferred-rotation system at Sonora, Tex., has resulted in sufficient range improvement to permit a 33-percent increase in stocking as compared to continuous grazing.

Grazing research should include studies on the entire ecosystem, not on just a few of the major species. Livestock performance per unit area may be more important in evaluating grazing studies than individual animal performance. Grazing studies should be flexible to permit consideration of fluctuation in plant attributes due to variations in weather conditions. Much additional study is needed to develop the most productive grazing scheme for each range operation.

Additional key words: Grazing management, grazing systems, continuous grazing, deferred-rotation grazing, rest-rotation grazing.

Introduction

This review is concerned primarily with research on grazing systems on native range in the 17 Western States. Only studies including some scheme of livestock manipulation other than continuous grazing are considered. Basic information on climate and vegetation are presented, so that results may be interpolated as widely as possible.

Grazing terminology follows that of the American Society of Range Management (*29*). Deferred-rotation grazing is to leave a range unit, or units, ungrazed for part of a year and to rotate the deferment among range units, in succeeding years. Rest-rotation grazing is to leave a range unit, or units, ungrazed for at least one year and to rotate the deferment from grazing among range units in succeeding years.

California Annual Rangeland

In the California valleys and foothills, annual grasses dominate the vegetation. Before the white man settled here, the area was probably dominated by perennial grasses, such as *Stipa cernua* Stebbins and Love, *S. pulchra* Hitchc., *Poa scabrella* (Thurb.) Benth. ex Vasey, *Melica imperfecta* Trin., *Sitanion hystrix* (Nutt.) J. G. Smith, and *Elymus triticoides* Buckl. (*37*). Because of fire and heavy grazing, the area is now dominated by annuals, *Avena fatua* L., *Bromus hordaceus* L., *B. mollis* L., *B. rubens* L., *B. rigidus* Roth., *B. tectorum* L., *Hordeum murinum* Huds., *H. pusillum* Nutt., *Festuca myuros* L., and *F. megalura* Nutt. While forbs are not abundant on this type, they are important to the grazing animal. The most important are *Medicago hispida* Gaertn., *Erodium cicutarium* (L.) L' Her., and *E. botrys* (Cav.) Bertol. On foothill ranges, an open savanna of *Pinus* L. sp., *Quercus* L. sp., and *Ceanothus* L. sp. forms an overstory over the annual grass type (*36*).

At Hopland, Calif., about 160 km. north of San Francisco and 91 cm. average annual pre-

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cipitation, the annual plants germinate in the fall, grow slowly until early spring, grow rapidly for about 6 weeks, and are usually mature and dry by June 1 (*10*). The size of the forage crop is related to weather conditions and may differ over 100 percent between years. The species composition also varies widely from year to year. The various species mature at different times during the spring. In planning a grazing strategy, several points are important; the short and variable time when species mature, variable maturation dates of desirable and undesirable plants, a wide difference in forage quality as related to available moisture and stage of maturity, and fluctuations in stage of maturity due to site (*10*).

Light utilization by livestock results in an increase of the tall annual grasses and a decrease of the desirable forbs. Heavy grazing use in the fall reduces plant growth in the winter (*2*). Heady (*9*) showed that mulch in excess of about 784 kg./ha. favored the tallest grasses. With no mulch, the vegetation was composed of undesirable forbs and grasses, and the herbage yields were reduced to about half of the mulch plots. From these studies, Heady (*10*) concluded that degree of utilization is important in determining the characteristics of the next crop.

Hervey (*14*) changed the species composition with burning treatments and Heady (*10*) with seeding and mulch manipulation. There seems little doubt that composition of the annual type can be changed, but the results are temporary and last only as long as the treatment is maintained.

Studies at the San Joaquin Experimental Range in central California (average annual precipitation of 46 cm.) showed a consistent advantage of yearlong-continuous grazing over seasonal grazing in breeding cow performance and calf weaning weights. The best balance of seasonally preferred plant species occurred on ranges grazed continuously yearlong (*5*). Similar results were obtained with sheep at Hopland. One range unit was divided into three divisions. One division was grazed in the early part of the growing season, one in the middle, and the third near the end of the growing season. The stocking period was rotated on an annual basis so that each division was grazed at each time only once in 3 years. The sheep were allowed to graze all three divisions during the dry season. The average weaning weight of lambs has been consistently higher in the range unit with yearlong-continuous grazing. The grazing treatments did not affect species composition, density, or herbage production.

The Pacific Bunchgrass Region

A study conducted at the Burgess Spring Experimental Range in northeastern California during 1936–51 (*16*) led to the design of a rest-rotation grazing system. Numerous lava flows and a few high peaks top an extensive plateau with an elevation that ranges from 1,068 to 2,440 m. Interspersed among the mountains are many plains and valleys. Some of the valleys are closed or poorly drained. Annual precipitation during 1935–54 averaged 46 cm. at Blacks Mountain Experimental Forest, 19 km. from Burgess Spring. On the average, 74 percent of the total occurred October 1-April 1, primarily as snow; 21 percent occurred April 1–July 1; and 5 percent during July 1–October 1. The snowpack averaged 46 cm. Average daily temperatures ranged from −5° C. in January to 14° C. in July.

Grassland, sagebrush, juniper, and pine types occupied 63 percent of the total area at Burgess Spring and furnished most of the forage used by livestock. The remaining area, of little use to livestock, was dominated by trees and shrubs. On 97 percent of the grazeable range, the primary species were bunchgrasses and other perennial plants that reproduce from seed. The grassland type was made up of wet meadow, closed basin, drained basin, and terrace sites. The major plants were *Festuca idahoensis* Elmer., *Poa nevadensis* Vasey ex. Scribn., *P. secunda* Presl., *Deschampsia caespitosa* (L.) Beauv., *Sitanion hystrix*, several *Carex* L. sp., and various forbs, shrubs, and trees.

The average seasonal development of herbaceous vegetation in the pine type was illustrated with *Festuca idahoensis*. Growth began about April 1 after the snowpack melted, and ended with seed ripening in early August. Half the seasonal yield of herbage was produced by the end of May and 90 percent by the end of June. Some plant species developed earlier and some later than *Festuca;* development also varied as much as 33 days from year to year. Herbage

production varied from 51 percent below average to 43 percent above average during the study periods (*16*). Clipping *Festuca* plants 3.8 cm. above ground surface at any time of the season reduced herbage production, basal cover, flower stalks, and height. The effects were more detrimental during periods of rapid growth. Basal area of *Festuca* plants was reduced about 50 percent the year following clipping, even when clipped 50 days following seed ripening. Four years of rest following 4 years of clipping at the milk stage resulted in little or no recovery of basal area. No flower stalks were produced in the first year of rest, but good production was obtained in subsequent years (*16*).

Cattle grazed season-long (late May-late October) in three fenced units; one was representative of cutover pine type, and two were representative of grassland types. In both the grassland and pine types, cattle grazed certain plants and certain areas more consistently than others. This resulted in a very uneven utilization of the range. The pattern of use was similar from year to year. Nearly all of the plant species in the pine type were grazed. However, 12 species supplied 95 percent of the forage consumed by cattle. The degree of use of a species was affected by its abundance, distribution, and the seasonal preference of the cattle. Use of *Festuca* averaged only 32 percent during 1936–46 in the pine type. It was 65 percent in 1945 and 80 percent in 1946. By 1946, grazed areas had fewer, smaller, and less productive *Festuca* plants than comparable ungrazed plots.

Gains of yearling heifers continued until early October, with the highest weight gains during the period of rapid *Festuca* growth (prebloom to maturity).

Hormay and Talbot (*16*) concluded that under continuous seasonal grazing, the desirable plants are destroyed by selective grazing. Selective grazing cannot be prevented by adjusting the stocking rate, but its harmful effects can be reduced by not grazing the range at appropriate intervals. The improvement of bunchgrass range depends on restoring the vigor of desirable plants so that there can be an abundant reproduction of these plants. To obtain reproduction, it is necessary to rest the range from grazing for three specific reasons: (1) To restore plant vigor, (2) to insure seed development, and (3) to insure seedling establishment. Based on the information developed at Burgess Spring, Hormay and Talbot proposed a rest-rotation grazing system with the following steps: (1) Graze all season for maximum livestock production, which may result in a reduction of plant vigor; (2) rest one or two seasons, until plant vigor is restored and there is some accumulation of litter; (3) rest until seed is ripe, then graze remainder of season to trample seed into soil and for maximum livestock production; and (4) rest one or two seasons, to permit establishment of new plants. The time required for each step depends on the growth requirements of the key species of the range.

The vegetation in the rested units constitutes a forage reserve that can be used in drought years. Range improvements, such as seeding and control of noxious plants, may be scheduled during rest periods. Stocking is based on the utilization of all forage species. Fairly heavy stocking forces greater use of the less palatable forage species and the less accessible grazing areas (*16*).

A trial of rest-rotation grazing was initiated on the Harvey Valley allotment of the Lassen National Forest in 1954 (*15*). That area has similar soils, vegetation, and climate to Burgess Spring. Good stands of *Bromus inermis* Leyss, *Agropyron desertorum* (Fisch.) Schult., and *A. intermedium* (Host) Beauv. were established by seeding and the native grass stands were improved on some areas by controlling the shrubby *Artemisia* L. sp.

There was a drought in Harvey Valley in 1959–61. The precipitation from July 1, 1960, to June 30, 1961, was 27 cm. or 59 percent of average. Ratliff and Rader (*31*) concluded that forage production was adequate for normal grazing and that the cattle made good gains. However, the stocking in 1961 was 81 percent of the rated capacity.

Ratliff (*30*) reported that preferential grazing occurred under rest-rotation grazing at Harvey Valley. He used a combination of fencing, salting, water development, and riding to obtain more even distribution of grazing.

Ratliff and Reppert (*32*), summarizing results of the grazing study at Harvey Valley after 13 years, concluded that the performance of individual animals was about the same with rest-rotation grazing as with season-long grazing. They

indicated that they still have a long way to go to double the capacity of the Harvey Valley allotment. In 1967, the livestock permittee was granted a length of grazing season increase with no change in permitted numbers. When the trial at Harvey Valley was established, it was expected that the grazing capacity would be doubled in 20 years (*15*).

Conifer Forest Ranges

Pinus ponderosa Dougl. ex Lawson forests are the most important forest grazing area in the Western United States. In Washington and Oregon, approximately 10 million ha. of forest grazing land furnishes summer forage for 250,000 cattle and nearly as many sheep (*34*). Effects of cattle grazing on herbage production were investigated 1954-66 on the Starkey Experimental Forest and Range near La Grande, Oreg. Elevations vary between 1,000 and 1,500 m. Annual precipitation averages 54 cm. Summer is the driest season. Open stands of *Pinus* and *Pseudotsuga menziesii* (Mirb.) Franco have an understory of *Carex geyeri* Boott., *Calamagrostis rubescens* Buckl., and a variety of forbs. Principal species in intermingled grassland openings are *Agropyron spicatum* (Pursh) Scribn. & Smith, *Poa secunda*, and *Danthonia spicata* (L.) Beauv. ex. Roem. & Schult.

Deferred-rotation and season-long grazing at three intensities were compared (*34*). The grazing period was about June 15 to October 15. Under deferred-rotation, the cattle were placed in half of the range for 2 months and then moved to the other half. The following year, the early and late pattern was reversed. Systems of grazing did not cause significant difference in production of any major plant group or species in the grassland type. In the forest type, heavy stocking reduced production of Carex from 455 kg./ha. to 227 kg./ha. *Carex* was very susceptible to grazing. It retained its production during the 12-year period only with light stocking in the deferred-rotation system. There was essentially no difference in reduction of *Carex* production under deferred-rotation and season-long grazing with moderate and heavy stocking. Skovlin and Harris (*34*) suggested that herbaceous forest vegetation may have been adversely affected by general reduction in May–July precipitation from 15 cm. in 1957 to less than 10 cm. in 1966. Initial intensive management practices such as fencing, water development, and salting were effective in increasing cattle use in the forest type (*8*).

Smith et al. (*35*) compared moderate rotation, heavy rotation, and moderate season-long grazing in the Big Horn Mountains near Burgess Junction, Wyoming. The elevation is 2,440 m. The major forage species is *Festuca idahoensis*, but there is a variety of herbaceous and browse species. The average annual precipitation is 79 cm.; about 40 percent occurs April–June. Frost and snow may occur at any time. The grazing season is June 20–September 20. In the rotation units, steers were moved among the three divisions at about monthly intervals. The rotation was such that the same division was not grazed at the same time in consecutive years. The study covered the 1959–64 period. There was no significant difference in daily gain between moderately stocked units (about 0.95 kg.). The daily gain on the heavy rotation unit averaged 0.82 kg. On soils of granitic origin, production of *Festuca* was maintained equally well on the three treatments. On soils derived from sedimentary deposits, the abundance of *Festuca* declined within the heavy rotation unit. Cover and production of *Festuca* was best maintained with season-long grazing. However, it generally was not utilized until mid-August on the season-long unit; whereas, it was moderately utilized as early as late July in the rotation units. In that area, *Festuca* makes little regrowth in the year it is grazed regardless of the time or amount of herbage removal (*35*). During 1961–63, use of *Festuca* averaged from 20 to 43 percent for the three grazing treatments. However, production declined during the study even though precipitation during the latter part of the study was above average. From the evidence presented, it appears that *Festuca* is not well adapted to grazing at the rate termed moderate at Burgess Junction.

Intermountain Shrub Region

Season-long grazing was compared with deferred-rotation grazing at the Squaw-Butte Experiment Station in southeastern Oregon during 1938–48 (*19*). The elevation is 1,375 m. and the average annual precipitation is 30 cm. Two-thirds of the precipitation occurs as snow in the

winter and the remainder as rain during the spring. The major plant species are *Artemisia tridentata* Nutt., *Agropyron spicatum*, *Festuca idahoensis*, and *Poa secunda*. Three range units were grazed with cows under a 6-year rotation system that included two consecutive years of late spring use (May 1–June 20), followed by 1 year of early summer grazing (June 20–August 10), 2 years of late summer grazing (August 10–October 1), and 1 year of early summer grazing. The growing season usually begins April 1 and ends June 30. A fourth range unit was grazed with cows season-long, approximately May 1 to October 1. The stocking rate was approximately the same under both systems and each year. The cows on the season-long range had an average annal advantage in weight gain of 4.1 kg. over those on the deferred-rotation range (*19*).

Grazing was more evenly distributed under deferred-rotation than under season-long grazing. Even though the season-long range unit was utilized more heavily than the units under deferred-rotation, vegetation density increased 22 percent under season-long grazing and 20 percent on the deferred-rotation units. The desirable grasses increased more than twice as much under season-long grazing as under deferred-rotation grazing. However, most of this increase was in the lightly grazed area in the season-long unit. Hyder and Sawyer (*19*) concluded that concentrating the cattle on a single unit of the three-unit, deferred-rotation system during the growing season for 2 consecutive years seriously reduced plant vigor. Hyder (*18*) recognized that the heavy grazing pressure during the growing season placed this deferred-rotation system at a disadvantage.

Northern Great Plains

Deferred-rotation and season-long grazing were compared at the Northern Great Plains Field Station during the period 1918–45 (*33*). The average annual precipitation during this period was 39 cm.—about half occurred from May–July and three-fourths from April–September. The dominant plant species are *Bouteloua gracilis* (H.B.K.) Lag. ex. Steud., *Agropyron smithii* Rydb., *Carex filifolia* Nutt., and *Stipa comata* Trin. & Rupr. The experimental range units were stocked with steers from May 16 to October 13. Each of the three divisions in the deferred-rotation system was grazed approximately one-third of the season. The 6-year rotation grazing included 2 consecutive years of spring use, 1 year of summer use, 2 consecutive years of late summer and early fall use, and 1 year of summer use.

Rogler (*33*) reported that moderate stocking was about the correct rate on a season-long basis. At that rate, vegetation changes were influenced primarily by differences in precipitation. The vegetation in the heavily stocked unit was definitely overgrazed for the 1918–34 period. During the wetter 1938–45 period, the heavily stocked unit was not considered overgrazed in any year. The vegetation in the rotation units did not show the adverse effects of grazing during 1918–34 as did the unit grazed season-long at the same rate. There was no evidence that the rotation units benefitted from any natural seeding that theoretically should have occurred in the fall grazed units.

The average increase in seasonal gain of steers on rotation over season-long at the same intensity was 16 kg. per head for 1918–34. The steers grazed season-long at the moderate rate gained 20 kg. per head more than those on rotation. During the period of 1938–45 when there was no shortage of forage in any of the range units, the steers in the moderate season-long unit gained 13 kg. per head per season more than those in the rotation units. The steers in the heavily stocked season-long unit gained 9 kg. per head more than those in the rotation units (*33*).

Rogler (*33*) concluded that steer gains could not be increased by using a rotation system when there was sufficient forage for season-long grazing. There would seem to be some merit in a rotation system for improving range that has been damaged by overgrazing. Rogler suggested, however, that complete deferment until the range condition recovers would be a more rapid method of improvement. A rotation system might be used when it is necessary to stock at a high rate during occasional years and with older cattle. One of the advantages of continuous grazing is that cattle have access to all the plants in the range unit when highest in nutritive value. Young cattle are less likely to gain under a rotation system because they do not utilize the mature for-

age in the summer and fall units as well as older cattle.

Lewis and others (*21*) compared season-long grazing with ewes at three intensities with rest-rotation grazing at a moderate intensity at Antelope Range near Buffalo, S. Dak., for the period of 1964–69. The average annual precipitation is 34 cm., but it was above average during this study period. Season of use was rotated on the four rest-rotation units, and one unit was rested each year. Time of ewe movement was based on utilization (about 50 percent). Year differences due to blizzards, spring storms, precipitation, and disease have contributed to a greater variation in the results than the grazing treatments. Contrary to results obtained during a dry phase (*7*), ewe performance in this wet phase under heavy grazing has been about equal to that of ewes on lightly and moderately grazed units. Rest-rotation grazing resulted in good range improvement. However, ewe and lamb production was lower with rotation grazing than with any of the season-long treatments. Heavy utilization in spots is a problem in all units. Combination stocking with sheep and cattle may alleviate this problem.

Southern Great Plains

Several grazing systems were compared at the Southern Great Plains Field Station near Woodward, Okla. (*24*). The average annual precipitation is 58 cm., 70 percent of which occurs April–September. The major plants are *Artemisia filifolia* Torr., *Bouteloua gracilis*, *Sporobolus cryptandrus* (Torr.) A. Gray, *Eragrostis trichodes* (Nutt.) Wood, *Andropogon scoparius* Michx., *A. hallii* Hack., *Panicum virgatum* L., *Paspalum stramineum* Nash, and *Leptoloma cognatum* (Schult.) Chase.

Continuous summer grazing (April–October) was compared with three-division rotation grazing at both heavy and moderate stocking rates (*23*.) The steers were rotated among divisions at 2-month intervals in 1942 and at 1-month or shorter intervals for 1943–51. Rotation grazing in 1942 reduced steer gains 29 kg. per head at the heavy rate and 17 kg. at the moderate rate. There was no real difference between gains in the other years when the rotation was shortened. The more desirable tall grasses, and also some of the forbs, increased most under rotation grazing at both rates. The less desirable *Paspalum stramineum*, *Leptoloma cognatum*, and *Bouteloua hirsuta* Lag. increased most under continuous grazing. However, McIlvain and Savage (*23*) concluded that this type of rotation could not be recommended over continuous grazing as an improved management practice.

McIlvain and Shoop (*24*) concluded that the following grazing systems have not proved superior to continuous yearlong grazing at the same stocking rates at Woodward: (1) summer and winter grazing, (2) alternate-year grazing, (3) three-unit rotations with rotations at 2-month, 1-month, 15-day, and 10-day intervals, (4) two-unit, 6-week, one-herd rotation when grass is growing, and (5) six-unit, 6-day, one-herd rotation. They cited some major reasons for the success of continuous yearlong grazing in the Southern Great Plains as (1) forage production is primarily dependent upon summer rainfall—and monthly forage production during the summer can vary from 22 to 672 kg./ha., (2) most species are grazed by cattle at one time or another; (3) many of the "increaser" species are excellent grazing plants and they may be very productive under certain conditions; (4) cattle compete with natural losses of forages and with other consumers; (5) young and regrowth forage is more palatable and more nutritious than more mature forage; (6) grazed plants save soil moisture for later green growth; and (7) favorable growing seasons combined with proper management allow ranges to recover a desirable species composition. Some additional reasons for the success of yearlong-continuous grazing may be (1) utilization during the growing season is light, and (2) lighter stocking per unit area means less soil compaction by livestock during wet periods.

Edwards Plateau

Merrill (*25*) compared continuous yearlong grazing at three intensities with deferred-rotation grazing at a moderate rate near Sonora, Tex. The major forage species is *Hilaria belangeri* (Steud.) Nash with minor amounts of *Tridens pilosus* (Buckl.) Hitchc. *Aristida* L. sp., *Bouteloua curtipendula* (Michx.) Torr., *B. hirsuta*, *Bothriochloa saccharoides* Rydb., *Andropogon*

seoparius, *Leptoloma cognatum*, and *Stipa leucotricha* Trin. & Rupr. There is an overstory of *Juniperus* L. sp. and *Quercus* L. sp. There is also a variety of forbs under certain weather conditions. The average annual precipitation is 61 cm. The average monthly precipitation is highest in spring and fall. Midsummer can be droughty. In the four-unit rotation system, each unit is grazed 12 months, then rested 4 months. Thus, during a 4-year cycle, each unit is deferred once during each of the 4-month periods. Stocking was with a combination of cattle, sheep, and goats. The study was initiated in 1949. After 11 years, the stocking rate of the units in the deferred-rotation system has increased 33 percent from 12.4 animal units/km.^{2} to 16.6 animal units/km.^{2} (*26*). These units carried the increased grazing pressure and at the same time made greater range improvement than any of the units grazed continuously. Average annual net returns for 1959–65 were \$1.78, \$2.91, and \$1.63 per ha. with continuous stocking at the rate of 6-, 12-, and 19-animal units/km.^{2}. The average net return for the same period on the rotation units was \$4.15/ha. (*26*).

A two-unit rotation, a four-unit rotation, and yearlong-continuous grazing were compared near Barnhart, Tex. (*17*). The most abundant grasses are *Buchloe dactyloides* (Nutt.) Engelm., *Hilaria belangeri*, and *H. mutica* (Buckl.) Benth. There are also other perennial and annual grasses and forbes, and an overstory of *Prosopis juliflora* (Sw.) DC. The mean annual precipitation is about 46 cm. with about the same average seasonal distribution as Sonora. The four-unit rotation is the same as the one described by Merrill (*25*). In the two-unit rotation, the units are alternately grazed and deferred for 3- and 6-month periods (for example, one unit is deferred March 1-June 1, grazed June 1-December 1, and deferred December 1-March 1). During a 2-year period each unit was deferred 12 months with deferment during each season. All treatments were stocked with cattle and sheep at 10-animal units/km.^{2} During 1959-65, the average annual net returns per animal unit were \$30.63, \$39.03, and \$41.71 for continuous, four-unit rotation, and two-unit rotation grazing, respectively (*17*). Huss and Allen (*17*) found that combination use of cattle and sheep was more profitable than grazing either class alone. Merrill (*26*) also found that combination grazing with cattle, sheep, and goats was more profitable at Sonora than using sheep alone or cattle alone.

Southern Rolling Plains

Fisher and Marion (*6*) compared rotation and continuous grazing at a moderate rate at Spur, Tex. The major forage species are *Buchloe dactyloides*, *Hilaria mutica*, and *Panicum obtusum* (H. B. K.). The average annual precipitation is 54 cm. The average monthly precipitation is well distributed from April-October. The remainder of the year is drier. The grazing season was about May 1-October 1. The rotation system consisted of grazing each of three units for one month and deferring it for two months for the 1942-49 period. Fisher and Marion (*6*) concluded that (1) rotation grazing did not improve the vegetational composition from 1942 to 1947; (2) rotation grazing increased differential use of *Buchloe* and *Hilaria* as the season progressed or in drought, and in some instances resulted in less moisture penetration on sites occupied by the more desirable species; and (3) gains of yearling steers grazing on the rotation units were slightly lower than those grazing on the continuous units.

Various grazing systems were compared at the Texas Experimental Ranch near Throckmorton during 1960-68 (*20*). The major plant species are *Stipa leucotricha*, *Buchloe dactyloides*, *Bouteloua curtipendula*, *Prosopis juliflora*, and *Condalia obtusifolia* (Hook.) Weberb. There is a wide variety of other plants in the flora. The average annual precipitation is 63 cm. There is a tendency for the precipitation to be distributed in the spring and fall with a slight depression in midsummer and in the winter. A moderate stocking rate with cows and supplemental feeding level of 0.7 kg./day of cottonseed cake during winter were used in comparing grazing systems. The three systems were yearling-continuous, two-unit rotation similar to that studied at Barnhart, Tex., by Huss and Allen (*17*), and a four-unit rotation similar to that studied at Barnhart by Huss and Allen and at Sonora by Merrill (*25*). Calf production per animal unit averaged 200, 208, and 221 kg. for the moderate continuous, two-unit rotation, and four-unit rotation, respectively, for the 8

years. Precipitation was near average or above average during the study.

Semidesert Grassland

A number of studies on the Jornada Experimental Range, 40 km. north of Las Cruces, N. Mex., have contributed to developing a grazing system (*13*). The major forage species on the light- to medium-textured soils are *Bouteloua eriopoda* (Torr.) Torr. and *Sporobolus flexuosus* (Thurb.) Rydb. *Hilaria mutica* and *Scleropogon brevifolius* Phil. grow on the heavier soils. Under certain weather conditions, there may be an abundance of a variety of forbs and annual grasses. The average annual precipitation is 22.5 cm. The average precipitation during the summer growing season is 12.5 cm. The average annual evaporation from a Weather Bureau pan is 225 cm. or ten times the precipitation. However, Herbel and Nelson (*13*) showed that precipitation averages had little meaning. During 53 years of record, 45 percent of the years had seasonal precipitation of less than 85 percent of average, and 34 percent of the years had seasonal precipitation greater than 115 percent of average. Furthermore, summer rainfall occurs as localized, convectional thunderstorms.

Forty years ago, there were two major vegetation types on the Jornada; one dominated by *Bouteloua eriopoda*, and the other dominated by *Hilaria mutica* and *Scleropogon brevifolius*. Because *Hilaria* and *Scleropogon* are more palatable and can withstand moderate grazing during the summer growing season, the grazing system consisted of grazing the *Hilaria-Scleropogon* type in summer and early fall, and then grazing the *Bouteloua* type from late fall until the next summer (*28*). However, considerable *Bouteloua* was lost during the severe drought of 1951-56 and due to a rapid increase of *Prosopis juliflora* on sandy soils (*3*). Now there are other vegetation types made up of a multiplicity of forbs and a few grasses. They can provide a considerable part of the forage crop in some years. Their production is not as reliable as the long-lived perennial grasses, but they have a high nutritive value (*27*). Herbel and Nelson (*12*) found that cattle grazed, to some extent, all species available to them, including a variety of forbs and shrub-like species. They also found that there were definite seasonal preferences for some species.

Using weather and plant information, and considering livestock needs, Herbel and Nelson (*13*) developed the Best Pasture Grazing System. The system consists of establishing an objective for each range unit and stocking accordingly. The system is opportunistic in that the use of forbes and short-lived grasses is maximized. They are of little value to the permanent range resource but contribute much to livestock nutrition. No set stocking plan is established for a specific time period because of considerable variations in weather conditions that affect plant growth. The system involves a rotation scheme where the livestock are moved when the vegetation on a deferred unit can be grazed to the advantage of both plants and animals as compared with the unit being grazed. In the large range units occurring in parts of the West, periodic opening and closing of watering places can be used to rotate grazing pressure to different areas within a range unit (*22*).

Conclusions

Studies on California Annual Rangelands have indicated that yearlong-continuous grazing is superior to seasonal grazing. However, species composition can be manipulated by grazing intensity, burning, and seeding. This may indicate that a highly flexible grazing system, involving some form of manipulation on part of a ranch operation, may provide a higher quality, quantity, or both of forage for part of the year.

There was only limited success with any grazing scheme other than continuous on rangelands grazed only for a part of the year. There has only been a modest increase of the grazing period at Harvey Valley following 13 years of rest-rotation grazing, and this may be due to range improvements such as seeding, brush control, fencing, and water development. At the Starkey Experimental Forest, the production of *Carex geyeri* was maintained only with light stocking in a deferred-rotation system. However, there was a spring drought during the study and *Carex* is very susceptible to grazing. At Mandan, the vegetation in the rotation units did not show the adverse effects of grazing during a period of below-average precipitation as did the unit grazed

season-long at the same rate. However, improvement in range condition would be more rapid under complete deferment for 1 or 2 years. At Antelope Range, rest-rotation grazing resulted in good improvement in range condition, but sheep production was lower than with season-long grazing. At Manhattan, Kans., an earlier study showed an advantage in vegetation response to deferred-rotation grazing, but a later study showed no advantage in vegetation by deferred-rotation grazing and a disadvantage in livestock performance (*1*, *11*).

In the northern part of the West, early plant growth is generally dependent upon winter-spring precipitation and periods of warm weather. Many workers recognize that grazing or clipping during the early part of seasonal growth is detrimental to subsequent plant vigor (for example, *4*, *16*). On ranges grazed seasonally, several studies have shown an advantage to spring deferment, but this must be balanced against the detrimental effects of concentrating livestock during this critical period of plant growth. At Squaw-Butte, nonuse during the growing season for 4 years did not overcome the detrimental effects of 2 consecutive years of concentrating the stock during the growing season. In the areas with short growing seasons, an important question, often not considered, is: how many of the desirable plants are actually grazed during the critical period of growth under a moderate stocking rate in a continuous system? At Burgess Junction, Wyo., *Festuca idahoensis* was not utilized until mid-August on the season-long unit, whereas it was moderately utilized as early as late July in the rotation units. It appears that any deferment period on ranges grazed only for part of a year should be brief, and that it should coincide with a critical period of growth. It should be recognized that the dates of this critical period vary from year to year depending on phenological development.

Another important consideration on ranges grazed seasonally is: Are range managers trying to maintain the right species? Undoubtedly, we must have species that will maintain the soil resource. However, from the evidence presented in this paper, *Festuca idahoensis*, *Carex geyeri*, *Agropyron spicatum*, and possibly others, are poorly adapted to grazing by livestock in some areas. Species that are not well adapted climatically also should not be considered important in many instances. For example, although *Bouteloua gracilis* is quite resistant to grazing, its production is low in some high altitudes in the Southwest.

At Woodward, a number of studies have shown no advantage to rotation grazing over continuous grazing in livestock performance. An early study showed an improvement in floristic composition due to grazing. The Woodward station is located in a broad regional ecotone with considerable fluctuations in floristic composition due to weather conditions. There is a reduction in percentage of tall grasses in the floristic composition in a series of dry years regardless of grazing treatment. Similarly, during a series of wet years, the tall grasses increase rapidly under any grazing treatment other than heavy stocking. This wide fluctuation in floristic composition due to weather conditions is common to some other parts of the West. With this situation, a classification of range condition at any point in time must allow for previous weather conditions.

Of the studies reviewed, the deferred-rotation system at Sonora, Tex., has shown the most striking results. At that location, a range unit is grazed with a combination of livestock for 12 months and deferred for 4 months. This infrequency of livestock movement means that the livestock must adjust to new forage conditions only once a year. Livestock are in a given unit for a complete cycle of plant growth. The major species, *Hilaria belangeri*, is quite resistant to heavy grazing. Another point is that there may be some growth of at least some of the plant species at anytime of the year when there is sufficient moisture. Therefore, a 4-month deferment during each third of the year every 4 years has resulted in a substantial improvement in carrying capacity.

Most studies have shown that livestock production per animal is the same or lower for a rotation system compared to continuous grazing. Generally, there must be an improvement in range condition, and subsequently in carrying capacity, to justify a rotation scheme using livestock performance as a criterion. Animal performance per unit area is more important than performance of individual animals. In some instances, it may take

several years to have enough range improvement to justify an increase in stocking.

When a rotation scheme is initiated, range improvements such as seeding, brush control, fencing, and water developments are often not properly credited for observed differences when compared to unimproved ranges. Rather, there is a tendency to credit the rotation scheme for observed improvements in range condition or animal performance. Any improvement that aids livestock distribution will result in greater productivity. The entire management plan, including both range improvements and grazing scheme, is the important consideration. All of the beneficial, economical practices should be integrated into the overall management plan.

Most grazing studies have been established at a fixed stocking rate. Downward adjustments in livestock numbers were made only in severe droughts. A fluctuating forage crop was given little thought in establishing grazing studies. This is probably another reason why many of the grazing studies have failed to show much improvement in range condition. When ranch operators adopt a grazing system other than continuous grazing, they often allow for a flexibility in time of grazing and deferral, and the number of livestock grazed. This flexibility may be the difference between success or failure of the grazing scheme.

A grazing system must be highly flexible. Plant and animal requirements must be considered. For example, some of the range units in a ranch operation may be manipulated to furnish highly nutritious forage during the time of the year when livestock need a higher plane of nutrition. This may be done at a sacrifice of some of the highly desirable range species on those units. Furthermore, it should be recognized that the critical growth stage of plants varies from year to year because of weather conditions. Due to grazing history and weather conditions, it may be more important to defer grazing in some years than in others.

Grazing systems should also be tailored to fit a variety of vegetation types, soil types, and herd management plans. This means that there may be considerable variation in specific details from one ranch operation to the next. In some areas, continuous grazing may be the most profitable system. It may be desirable to use a certain grazing system to attain a certain measure of improvement and then change to a different system.

Much has been learned about grazing management. However, much needs to be done to develop and adapt the most productive grazing scheme to each range operation. In many grazing studies, the major emphasis has been centered on a few species. The value of all plants growing on an area must be considered. Even minor amounts of a few species may contribute much to animal performance for a brief, but critical, part of the year. Few studies have given attention to forbs and shrubs. Grazing research should include studies on the effects on the entire ecocystem, not just the effects on the livestock and a few of the major plant species.

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